A STUDY OF THE MOTIONS OF FORTY-EIGHT DOUBLE STARS

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The double stars examined in the following investigation will all be recognized as old and well-known pairs, on each of which a large number of measures have accumulated. Each of these has shown a considerable motion since discovery, but although orbits have been computed for several of them, there is no case in which certain knowledge of the true form of the orbit can be had at this time, nor with the greater number of these pairs is it even certain that the motion is orbital at all. It was, in fact, in view of this uncertainty that the following computations were undertaken. The complete list of double stars at present known to us was examined, and all of those in which, notwithstanding the large number of measures made upon them, it seemed uncertain whether the motion is rectilinear or orbital were selected for study. The primary object was to ascertain, when possible, in which pairs rapid motion during the next few years might be reasonably expected and those in which the distance is now near a maximum value. It is upon such pairs that observations are most urgently needed, while upon those for which the analysis gives no indication that the companion is now near a critical part of the orbit the multiplication of observations is at the present time unnecessary.

It is well known that with the type of pairs here considered, in which less than two quadrants have been described by the companion, a series of widely different orbits may be obtained, any one of which may satisfy the observations within the limits of error naturally to be expected; and this, even although it may afterward appear that the motion is only rectilinear and the pair is not a true binary system. It was therefore thought best not to begin each computation by so adjusting the six constants of the orbit that the observations should be represented by them, but rather to assume that the motion is rectilinear, and having found the straight line which best represents all the observations to examine in each case whether there is definite evidence that the motion of the companion in the straight line is, or is not a uniform motion. If a continuous progressive change is found, greater than can be assumed due to errors of observation, it is evident that the motion is not rectilinear, while in the many cases in which the variations are less, or but little greater, than might be attributed to errors of observation the evidence for the binary character of the system must be regarded as inconclusive.

The first step in each case was to form suitable means of the numerous observations. Among the earlier measures, those of Maedler and also those of the few occasional observers were rejected, especially since in no case were there wanting accurate observations by Σ, 0Σ and Δ during the same intervals. Practically all modern observations were, however, included, and these were

weighted in proportion to the number of nights, except that at least double weight was always given to the measures of Aitken and Hussey with the 36-inch and to those of Burnham with the 40-inch.

The approximate rectilinear path having been found, the differential corrections Δv, ΔT and Δd to the mean motion, the time of closest approach and the direction, respectively, were next found by a least square adjustment, measures of angle, only, being employed; the distance at closest approach was next found from the weighted means of the measured angles and distances. It was assumed that the line as thus finally adjusted was the best determination of the path obtainable upon the hypothesis that the path is rectilinear. The average velocity, v, along the path was finally compared with the observed velocity at different epochs in order to ascertain any systematic variation that might exist.

It is found convenient to group the pairs examined into five classes, determined by the results of the investigation as follows:

Class A.—The velocity shows a decided and certain increase. Rapid motion in angle is to be expected, and careful measures, particularly of angle, are especially needed at this time.

0Σ 20, (Burnham's General Catalogue, No. 479). Though for 50 years after discovery the velocity remained nearly constant, (about 0″.016), it has, since 1897, very decidedly increased, (to 0″.036), and orbital motion is certain. The period will, however, much exceed the value, 136.2 years, assigned by Glasenapp.

Σ 208, (1074). It was found quite impossible to represent both the earlier and the later observations by a single rectilinear path. The velocity is now nearly three times the average velocity and the stars are near their minimum distance.

Σ 963, (3625). The motion is here very slow, but there is a systematic increase in v, from 0″.0070 in 1839 to 0″.0131 in 1908.

Σ 1306, (4923). The observations from 1845–'65 are discordant but there is a remarkable increase in v during recent years. Undoubtedly binary, and now so near the least distance that an entry into the first quadrant may be expected during the next few years. The brighter component (5.0 magnitude) is one of Newcomb's Fundamental Stars and is contained in the American Ephemeris. As we, of course, know nothing of the location of the center of gravity between this and its 8.5 magnitude companion, it would seem that this is unsuitable for use as a fundamental star.

Σ 1834, (6832). The distance in this pair is now but little greater than 0″.1 and the measures since 1892 are hopelessly inconsistent. Analysis of the motion from discovery until the date mentioned shows a steady, and finally rapid, increase in velocity. The angle of the companion has probably increased 180° during the past few years.

Σ 113, (707) and Σ 2576, (9602), also show a definite and certain increase of velocity in recent years.

Class B.—The velocity shows a definite diminution. The stars are nearly at their maximum distance. Measures are now needed to fix the position of apastron, but the angle will probably change but little. The distance should be measured with special care.

Σ 305, (1427); Σ 1457, (5508); 0Σ 261, (6415); and 0Σ 288, (7049) all show a decided and progressive diminution of the velocity. In the last, (0Σ 288), it is, in fact, uncertain whether the motion did not wholly cease about 1912, and the two stars begin to draw together.

Class C.—A systematic and certain variation of the velocity, but the companion is not certainly at either periastron or at apastron.

The most striking examples in this class are: Σ 400, (1747), in which the velocity has been steadily increasing since discovery; 0Σ 215, (5365), in which the analysis shows the maximum velocity to have been attained about 1893; Σ 1865, (6955), in which the velocity mounted quite suddenly to a value nearly four times the average about 1897, when the stars were closest together, and which has since been rapidly diminishing, and Σ 2118, (7834), in which the maximum velocity was attained about 1895. In all of these cases the rise and fall of the velocity is very striking. There were also found to belong to this class,—Σ 2, (21); Σ 535, (2161); Σ 1536, (5765); and Σ 1687, (6296).

Class D.—The velocity apparently varies, (sometimes quite irregularly), and orbital motion is strongly suggested, but it is in no case entirely certain. But few observations are required on these pairs at this time.

Fourteen of the 48 pairs were found to belong to this class in which, though orbital motion might be strongly suspected, it is, nevertheless, not yet entirely certain. These pairs are,—

Σ 13, (92),	0Σ 159, (3678),	Σ 1757, (6530),
Σ 138, (830),	Σ 1175, (4402),	Σ 2315, (8548),
0Σ 50, (1568),	Σ 1338, (5030),	Σ 2434, (8986),
Σ 460, (1952),	Σ 1429, (5421),	0Σ 413, (10533),
	Σ 1517, (5707),	0Σ 437, (10922).

Class E.—No certain trace of orbital motion. A multiplication of observations on these pairs is unnecessary.

Fifteen pairs showed no certain trace of orbital motion:

H 1968, (216),	0Σ 92, (2445),	Σ 1643, (6174),
0Σ 18, (374),	*H* 3823, (3112),	Σ 1883, (7013),
0Σ 43, (1365),	Σ 1104, (4098),	0Σ 297, (7320),
Σ 367, (1623),	Σ 1423, (5385),	Σ 2199, (8118),
Σ 567, (2272),	0Σ 237, (5859),	Σ 2574, (9570).

Summary.—The final summary for the 48 pairs examined is as follows:

Class A....7 Pairs, Class B....4 Pairs, Class C....8 Pairs.

Total pairs in which orbital motion is certain.....19

Class D....14 Pairs, Class E....15 Pairs

Total pairs in which the evidence thus far is negative.....29